ENVIRONMENTAL Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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# Removal of Iron and Manganese From Drinking Water - Technical Version

This document provides a technical description of treatment options for removing iron and manganese from drinking water. The technical abbreviation for iron and manganese is Fe/Mn, respectively. These contaminants act similarly and are treated by the same processes and thus are discussed together in this document. This document is intended to provide detailed information useful when purchasing a new Fe/Mn treatment device or diagnosing operational problems with existing equipment.

## UNDESIRABLE EFFECTS OF IRON AND MANGANESE

Fe/Mn occur naturally in New Hampshire's geology both in the bedrock and sand/gravel deposits. Fe/Mn dissolve into water as acidic rainfall percolates through the soil and bedrock. In higher concentrations Fe/Mn cause the following problems.

1. **Staining**. Fe/Mn stain laundry and water use fixtures. Where the concentration of iron is high, the color of the staining theoretically tends toward orange-brown. Where manganese predominates, the discoloration is typically more black or gray. In most New Hampshire situations, orange-brown tends to predominant whatever is the ratio of Fe to Mn.

2. **Taste**. Fe/Mn cause a metallic or vinyl type taste in the water.

3. **Appearance**. Fe/Mn will often give an oily, “crusty” sheen to the water surface. (Actual oil does not appear “crusty” when disturbed, but “feathers out” like a rainbow).

4. **Sulfur Taste**. Hydrogen sulfide, which causes a “rotten egg” odor, can also be liberated from the soil by the same conditions (i.e. low dissolved oxygen and low pH) that cause Fe/Mn to dissolve in water. Hydrogen sulfide is frequently encountered in water with excessive Fe/Mn. Some of the treatment methods used to remove iron and manganese will also remove hydrogen sulfide gas.

5. **Clogging**. Certain bacteria thrive in the presence of Fe/Mn. These non-health related bacteria can clog strainers, pumps, and valves. Periodic or continuous chlorination is the best means to control Fe/Mn bacteria. Once present, Fe/Mn bacteria are difficult to eradicate from a well. There is no relationship between total coliform and Fe/Mn bacteria.

## HEALTH EFFECTS

Both Fe/Mn are essential nutrients for all life, and a typical daily dietary intake for humans is approximately 5 milligrams for each of these minerals.

EPA has established "secondary" limits for Fe/Mn in drinking water as shown below. These limits are based on **aesthetic concerns** only. These limits are called secondary maximum contaminant levels (SMCLs):

- Iron = 0.30 mg/L (milligrams per liter) or ppm (parts per million)
- Manganese = 0.05 mg/L

Recently EPA has indicated that there is a **health concern** with high levels of manganese in drinking water. Manganese may affect neurological and muscle function in humans. While EPA is developing their health-based drinking water standard, the Environmental Health Program of DES has adopted an interim health-based standard for manganese of 0.84 mg/L. For additional health information concerning manganese, visit the fact sheets web page at www.des.nh.gov/organization/commissioner/pip/-factsheets/ard/index.htm and read document ARD-EHP-15.

In most cases in New Hampshire, the staining problems described above do not become objectionable until the actual concentrations of Fe/Mn are at least double the secondary standards. Treatment is not thought to be necessary to remove minor Fe/Mn levels above these aesthetic SMCLs unless you are actually experiencing a staining problem.

## FACTORS THAT MUST BE KNOWN WHEN CHOOSING A TREATMENT PROCESS

### Type of Fe/Mn Present

Fe/Mn may be present in any of **three** different forms ranging from clear to discolored as described below. In some wells Fe/Mn may be present in multiple forms simultaneously**. Not all treatment methods work on all forms of Fe/Mn.**

1. **Your water is totally clear when drawn from the tap (80 percent of New Hampshire cases).** Fe/Mn is present in the dissolved form. The terms “clearwater iron” or “clearwater manganese” are often used to describe this form. The scientific name for clearwater iron is called “ferrous” and for manganese, “manganous.”

2. **Your water is rusty colored when drawn from the tap (20 percent of New Hampshire cases).** When exposed to oxygen or other oxygen like chemicals, clearwater Fe/Mn will precipitate to form fine brownish (ferric) or blackish (manganic) “rust” particles. The tendency to precipitate these minerals is also influenced by changes of water temperature, higher pH and other factors. It is the precipitated forms of Fe/Mn which stain water use fixtures and discolor laundry. These “rust particles” will settle out if the water is not disturbed.

3. **Your water has a yellow tint, but is totally transparent and the color does not settle out with time (less than 1% of New Hampshire cases).**
In this case the Fe/Mn have probably combined with dissolved organic matter in the water. This form is commonly called colloidal or organic iron and/or manganese. It is more commonly found in surface water than in groundwater; therefore, you should also have the bacterial quality of the well checked if organics are present. Testing for the organic components, called tannins, gives you a sense of the potential for formation of colloidal Fe/Mn.

This form of Fe/Mn will not settle out when the water is undisturbed and is too small to be removed by filtration. Organic iron cannot be removed by a conventional cation exchange (i.e., water softener) treatment, but can possibly be removed by the anion exchange method. Colloidal Fe/Mn can be difficult to remove.

**Water Quality Tests**

In order to determine which treatment process will work for your particular water quality, you must know certain water quality factors. Typically important factors for Fe/Mn removal include:

1. The concentrations of Fe/Mn.
2. pH (acidity) and hardness.
3. Dissolved oxygen for some treatment types; this must be field measured.
4. The presence of Fe/Mn bacteria.

When sampling, be sure to let the cold water run for five minutes and remove any aerators or filters before taking your sample. This will help ensure the water has come directly from the well and that the sample from the faucet is representative of the water in the well. If you have rusty water coming directly from the well, it is necessary to flush all past accumulated sediment to waste in order to prevent capturing a nonrepresentative sample. The roil up of previously settled Fe/Mn gives the opportunity for the overstatement of the amount of Fe/Mn normally present.

**OVERVIEW OF ALL CATEGORIES OF TREATMENT**

Shown below is a summary of available methods for treating Fe/Mn. A separate explanation for each treatment type is then presented.

**SUMMARY OF Fe/Mn TREATMENT OPTIONS**

| | **To control discoloration without removal of Fe/Mn** | **To control discoloration, by removal of Fe/Mn** | |
|---|---|---|---|
| **Fe/Mn Condition** | Dissolved Fe/Mn | Dissolved Fe/Mn Only | Precipitated/Dissolved |
| **Water's Appearance** | Clear water | Clear water | Rust or blackish color |
| **Appropriate Fe/Mn Treatment Method** | **Sequestering** Add sequestering chemicals, typically phosphate, to prevent staining. Not normally a homeowner approach. | **Water softening** (cation exchange) | **Oxidation/Filtration** Chlorine, potassium permanganate, aeration, followed by filtration, using greensand, Birm, cartridge or bag filters. |

**NO Fe/Mn REMOVAL: STAIN PREVENTION IS ACCOMPLISHED BY ADDITION OF SEQUESTERING CHEMICALS**

The undesirable staining caused by Fe/Mn can sometimes be minimized by adding a food grade polyphosphate chemical to the water to prevent the formation of the rusty colored forms of Fe/Mn. These chemicals “coat” and “tie up” the dissolved Fe/Mn ions preventing a reaction with oxygen and subsequent precipitation. (An ion is the dissolved form of an atom or compound.) Sequestering prevents the staining effect but does not remove Fe/Mn.

Sequestering **only** works when the Fe/Mn is initially in the dissolved “clearwater” form. Sequestering chemicals may be reasonably effective for iron in concentration as high as 0.6 mg/L and for manganese concentrations as high as 0.10 mg/L. As the Fe/Mn concentration continues to increase, the level of expected success using a sequestering method decreases.

The sequestering agent is added by a chemical feed pump which starts and stops with your water well pump. More phosphate chemical is needed for manganese than for iron. Maintenance is minimal.

**Advantages of Sequestering**

- Low cost equipment and chemicals.
- Small space requirements.
- Other water quality factors are not too important.

**Disadvantages of Sequestering**

- The effectiveness of the treatment is reduced at higher water temperatures, when the water is aerated, or when bleach is added.
- Sequestering chemicals lose effectiveness with time. They revert from the “poly” to the “ortho” form of phosphate.
- Phosphate compounds could foster bacterial growth within your home plumbing system and residual phosphate in septage causes weed and algae growth in lakes.
- Not effective for that portion of the Fe/Mn that has already turned rusty colored.
- Not commonly used in a private well single family home situation.

**REMOVAL OF DISSOLVED Fe/Mn USING WATER SOFTENERS**

A water softener removes Fe/Mn which is in the dissolved “clearwater” form. Softening also removes calcium (Ca) and magnesium (Mg) ions which are the primary minerals responsible for “hard” water. The treatment process consists of passing the water through an ion exchange resin media bed. The Fe/Mn ions and also calcium and magnesium ions in the water are “exchanged” for sodium ($Na^+$) ions which have been temporarily stored in the resin material.

As the hardness and Fe/Mn are removed from the water, sodium is added proportionally. For every 10 mg/L of hardness and Fe/Mn removed, approximately 5 mg/L of sodium will be added to the treated water. For those concerned with elevated sodium levels in their drinking water, potassium chloride (KCl) can be used in place of sodium chloride (NaCl). The cost of KCl is higher than sodium chloride. Potassium, one of the three principal elements in fertilizer, is a valuable soil nutrient.

Eventually the removal capacity of the ion exchange resin material will become exhausted and the media will need to be regenerated. The regeneration process begins with a physical backwash of the media to remove fine particles. The resin is then immersed in a strong salt brine solution. The sodium (or potassium) from the salt enters the resin and displaces the previously removed Fe/Mn and hardness. After a period of time (approximately 20 minutes), the remaining brine along with the displaced “loosened” Fe/Mn and hardness are flushed out of the device and disposed of into a dry well, septic tank, or sewer. Studies by the Water Quality Association (a trade organization of the home water conditioning industry) indicate that waste brine does not injure leach fields or septic tanks. Additional studies are now underway.

Ion exchange (IE) softening is described as effective for water containing less than 2-5 mg/L of dissolved Fe/Mn. IE will not work at all where the Fe/Mn have turned to a rusty color. Other aspects of water quality such as pH or alkalinity are not important in the operation of IE.

Hardness in drinking water is normally categorized as shown:

| **Concentration (mg/L as $CaCO_3$)** | **Description** |
|---|---|
| 0 to 75 | soft water |
| 76 to 150 | moderately hard water |
| 151 to 300 | hard water |
| 301 and up | very hard water |

Sometimes hardness is expressed as grains per gallon (gpg). One grain per gallon equals approximately 17.2 mg/L. A hardness level of less than 100-150 mg/L generally is not considered sufficiently hard to need water softening however, this is a judgment decision.

In general, DES does not recommend the use of softeners to treat only Fe/Mn due to the disadvantages listed below. Where both Fe/Mn and hardness are high, softening is an appropriate treatment technique. For more information, visit the fact sheets webpage at www.des.nh.gov/organization/commissioner/-pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-12, "Ion Exchange Treatment of Drinking Water," and WD-DWGB-3-14, "Sand and Sediment in Drinking Water."

**Advantages of Water Softening**

- Softener resin can be rejuvenated and re-used.
- IE can consistently remove dissolved Fe/Mn from water to extremely low levels.
- Softeners have lower backwash water requirements than oxidizing filters.
- The Fe/Mn removal is not appreciably affected by the water's pH or other factors.

**Disadvantages of Water Softening**

- Softening will not operate satisfactorily if iron bacteria or rusty colored water exists, even if occasionally. If particles are present, a sediment prefilter is often placed before the resin tank.
- A water softener will not remove hydrogen sulfide odor.
- Water softeners produce waste brine that must be disposed of. If you do not have a sewer, disposal of the waste brine will likely be into the ground. This creates the potential of polluting the groundwater and subsequently your own well or the wells of your neighbors downhill.

The newest design concept for water softeners incorporates the regeneration mode called demand regeneration. This approach allows the frequency of softener regeneration cycles to be reduced. The controls on these devices include those that measure the water's electrical conductivity or those that measure the volume of water treated. In each case, rejuvenation is triggered based on actual need rather than time passage on a time clock. Historically clock timers will backwash a water softener whether it needed regeneration or not, such as during vacation periods. This excessive backwashing needlessly increases salt use and the generation of waste brine.

In addition, customers can also set the softener unit to use a high or low level of salt during each regeneration cycle. Use of a low level of salt (6-7 pounds) per cubic foot of resin gives the best efficiency of contaminant removal per pound of salt used. We recommend this low level regeneration option. Visit the fact sheets webpage at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-12 for a discussion.

**GENERAL INTRODUCTION TO OXIDIZING FILTERS: REMOVAL OF Fe/Mn**

In oxidizing filters, all Fe/Mn is first purposely converted to the rusty colored form. These larger particles are then strained out on the filter media. The filter media is periodically backwashed to remove the collected rust particles. The Fe/Mn laden backwash is discharged into a dry well, leach field, or sewer.

**Fe/Mn REMOVAL USING POTASSIUM PERMANGANATE GREENSAND FILTRATION**

In this filtration type, potassium permanganate ($KMnO_4$), a purple crystal or liquid, is used to precipitate (meaning, to convert to a solid) Fe/Mn. Chlorine or aeration may also be used. The $KMnO_4$ can be added either continuously (at a very dilute concentration) or in a more concentrated form at the time of backwash (batch mode). In the latter option, the $KMnO_4$ enhances a special oxygen rich coating on the greensand media that causes precipitation of the Fe/Mn within the media during normal filter operation.

For this filtration type, the pH needs to be over 7, at a minimum, and preferably over 7.5 to assure full precipitation of Fe/Mn. Where manganese concentration is high, a pH greater than 8 is recommended. Where the pH is low, a chemical feed pump may be needed to raise the pH. A contact/detention tank is sometimes installed to allow more time for the oxygen and the Fe/Mn contaminants to produce a sizeable rust particle.

$KMnO_4$ greensand filtration is effective for very high levels of Fe/Mn. Where the manganese level is high, feeding a dilute chlorine solution may improve manganese removal. $KMnO_4$, chlorine or aeration can also remove hydrogen sulfide odor. Visit the fact sheets webpage at www.des.nh.gov/organization/-commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-3-16, "Hydrogen Sulfide in Drinking Water."

Periodically the greensand filter is backwashed. The rusty backwash water is typically discharged into an approved dry well, septic tank, or sewer. This discharge of Fe/Mn to a septic field does not have the groundwater pollution consequences of water softener brine.

**Advantages and Constraints of Oxidizing Filters**

- Filter can be backwashed and recharged for re-use.
- Can consistently remove high concentrations of Fe/Mn to extremely low levels.
- Adds no sodium to the water.
- Can significantly reduce "rotten egg" odors.
- There are minimum flow rates required for backwash.

**Disadvantages & Limitations of Oxidizing Filters**

- The pH of the water is critical to the filter's effective operation. The raw water pH should be 7.0 or higher for iron (pH = 8 or higher for manganese) or pH adjustment will be necessary. If you have a shallow (dug) well, an inexpensive way to raise the pH is to add marble chips (also called calcite chips) to the well. Don't forget to disinfect the well after this operation. Calcite will somewhat increase the water's hardness. Visit the fact sheets webpage at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-3-4, "Corrosivity of Water Supplies."
- The rate of required backwash water is high. Keep this in mind when selecting the size of the oxidizing filter suitable to your source water output. Where well output is low and the required filter size is large, two smaller filters might be substituted so that each can be backwashed separately. This duplication would create additional expense.

**Fe/Mn REMOVAL BY VENTURI AERATION - FOLLOWED BY FILTRATION**
This is a variation of the oxidation filtration method. Many homeowners would prefer not to add foreign chemicals to their water supply. One filtration media that accommodates this preference is the so-called “birm” catalyst media. Where dissolved oxygen in the water is low, ordinary air is added to the water by a special venturi nozzle. The mixture of air and water then passes into a detention tank where the oxygen dissolves into the water. An air release valve allows the unused nitrogen and excess air to be bled off. The water then enters the birm media filter tank. The coating on the birm media acts as a catalyst to force the completion of the chemical reaction between the dissolved oxygen and Fe/Mn so as to form Fe/Mn rust particles.

The Fe/Mn precipitate is then physically caught by the birm media. The birm is backwashed periodically to remove the precipitates, but no chemical rejuvenation of the birm is needed. This method is effective for very high levels of Fe/Mn.

**Constraints When Using Birm Media**
Where the dissolved oxygen level of the raw water is above 15 percent, there is no pressing need to install the venturi nozzle, however, such installation is often still done in view of the low cost of the device and in consideration of possible source water variation. The pH should be over 7.0 for iron and 8.0 for manganese. If both Fe/Mn are substantially present, the pH should be under 8.5 so as to not produce colloidal iron. There are minimum flow requirements for backwash.

Other manufacturer comments recommend that tannins and hydrogen sulfide should be low. These other contaminants will produce a precipitate that fouls the media. Organic material should be less than 5 ppm. Effectiveness of the birm media will be reduced by long term exposure to chlorine, however, short term chlorination to kill Fe/Mn bacteria is acceptable. No appreciable phosphate should be present. The precipitate of Fe/Mn tends to lower the pH and thus the alkalinity or pH adjustment may be needed. An “enriched” media is often necessary to remove manganese.

**Advantages**

- No "foreign" chemicals are added to the water.
- Low labor cost.
- Can handle a wide range of Fe/Mn levels.
- Can often reduce some objectionable odor.

**Disadvantages**

- Few

**BAG FILTRATION**
This equipment is often used to remove Fe/Mn which is fully oxidized as the water comes from the well. The particles are removed from the water by passage through bag filters. The cost of this system is low. The bags must be manually cleaned, which creates higher operational costs.

**TREATMENT TYPES NOT RECOMMENDED**
**Magnetic/Electronic Fe/Mn Removal Devices**
The Water Quality Association (the professional association representing the home water treatment industry) has indicated that there is no proof that magnetic/electronic Fe/Mn removal devices are effective. It is difficult to obtain objective test data for methodologies that do not remove the contaminants. Visit the fact sheets webpage at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-10, “Magnetic/Electronic Water Treatment Devices.”

**Reverse Osmosis**
This process will become clogged by rust particles, Fe/Mn bacteria, and silt, and cannot be regenerated. New membranes would be required frequently. Visit the fact sheets webpage at www.des.nh.gov/-organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-11, “Reverse Osmosis Treatment of Drinking Water.”

**PURCHASING A WATER TREATMENT SYSTEM**
For additional considerations concerning the layout, installation, maintenance, repair, and guarantee of private home water treatment systems, visit the fact sheets webpage at www.des.nh.gov/organization/-commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-5, “Considerations When Purchasing Water Treatment Equipment.”

This document has been prepared for educational purposes and should **not** be the only basis for deciding which type of Fe/Mn treatment system to purchase or what improvements should be made to an existing system. Your decision should be based on information from equipment suppliers and other independent professional sources.

## For Additional Information
Please contact the Drinking Water and Groundwater Bureau and the New Hampshire Water Well Board at (603) 271-2513 or dwgbinfo@des.nh.gov or visit our website at www.des.nh.gov/organization/divisions/-water/dwgb/index.htm. All of the bureau’s fact sheets are on-line at www.des.nh.gov/organization/-commissioner/pip/factsheets/dwgb/index.htm.

Note: This fact sheet is accurate as of October 2008. Statutory or regulatory changes or the availability of additional information after this date may render this information inaccurate or incomplete.